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THE ORGANIZATION OF SCIENTIFIC RESEARCH.

BY SIMON NEWCOMB, LL.D., UNITED STATES NAVY.

THE claims of scientific research on the public were never more forcibly urged than in Professor Ray Lankester's recent Romanes Lecture before the University of Oxford. Man is here eloquently pictured as Nature's rebel, who, under conditions where his great superior commands "Thou shalt die," replies "I will live." In pursuance of this determination, civilized man has proceeded so far in his interference with the regular course of Nature that he must either go on and acquire firmer control of the conditions, or perish miserably by the vengeance certain to be inflicted on the half-hearted meddler in great affairs. This rebel by every step forward renders himself liable to greater and greater penalties, and so cannot afford to pause or fail in one single step. One of Nature's most powerful agencies in thwarting his determination to live is found in disease-producing parasites. "Where there is one man of first-rate intelligence now employed in gaining knowledge of this agency, there should be a thousand. It should be as much the purpose of civilized nations to protect their citizens in this respect as it is to provide defence against human aggression."

It was no part of the function of the lecturer to devise a plan for carrying on the great war he proposes to wage. The object of the present article is to contribute some suggestions in this direction; with especial reference to conditions in our own country; and no better text can be found for a discourse on the subject than the preceding quotation. In saying that there should be a thousand investigators of disease where there is now one, I believe that Professor Lankester would be the first to admit that this statement was that of an ideal to be aimed at, rather

than of an end to be practically reached. Every careful thinker will agree that to gather a body of men, young or old, supply them with laboratories and microscopes, and tell them to investigate disease, would be much like sending out an army without trained leaders to invade an enemy's country.

There is at least one condition of success in this line which is better fulfilled in our own country than in any other; and that is liberality of support on the part of munificent citizens, desirous of so employing their wealth as to promote the public good. Combining this instrumentality with the general public spirit of our people, it must be admitted that, with all the disadvantages under which scientific research among us has hitherto labored, there is still no country to which we can look more hopefully than to our own as the field in which the ideal set forth by Professor Lankester is to be pursued. Some thoughts on the question how scientific research may be most effectively promoted in our own country through organized effort may therefore be of interest. Our first step will be to inquire what general lessons are to be learned from the experience of the past.

The first and most important of these lessons is that research has never reached its highest development except at centres where bodies of men engaged in it have been brought together, and stimulated to action by mutual sympathy and support. We must call to mind that, although the beginnings of modern science were laid by such men as Copernicus, Galileo, Leonardo da Vinci and Torricelli before the middle of the seventeenth century, unbroken activity and progress date from the foundations of the Academy of Sciences of Paris and the Royal Society of London at that time. The historic fact that the bringing of men together, and their support by an intelligent and interested community, is the first requirement to be kept in view can easily be explained. Effective research involves so intricate a network of problems and considerations that no one engaged in it can fail to profit by the suggestions of kindred spirits, even if less acquainted with the subject than he is himself. Intelligent discussion suggests new ideas and continually carries the mind to a higher level of thought. We must not regard the typical scientific worker, even of the highest class, as one who, having chosen his special field and met with success in cultivating it, has only to be supplied with the facilities he may be supposed to need in

order to continue his work in the most efficient way. What we have to deal with is not a fixed and permanent body of learned men, each knowing all about the field of work in which he is engaged, but a changing and growing class, constantly recruited by beginners at the bottom of the scale, and constantly depleted by dropping away at the top. No view of the subject is complete which does not embrace the entire activity of the investigator, from the tyro to the leader. The leader, himself, unless engaged in the prosecution of some narrow specialty, can rarely be so completely acquainted with his field as not to need information from others. Without this, he is constantly liable to be repeating what has already been better done than he can do it himself, of following lines which are known to lead to no result, and of adopting methods shown by the experience of others not to be the best. Even the books and published researches to which he must have access may be so voluminous that he cannot find time to completely examine them for himself; or may be inaccessible. All this will make it clear that, with an occasional exception, the best results of research are not to be expected except at centres where large bodies of men are brought into close personal contact.

In addition to the power and facility acquired by frequent discussion with his fellows, the appreciation and support of an intelligent community, to whom the investigator may, from time to time, make known his thoughts and the results of his work, add a most effective stimulus. The greater the number of men of like minds that can be brought together and the larger the community which interests itself in what they are doing, the more rapid will be the advance and the more effective the work carried on. It is thus that London, with its munificently supported institutions, and Paris and Berlin, with their bodies of investigators supported either by the Government or by various foundations, have been for more than three centuries the great centres where we find scientific activity most active and most effective. Looking at this undoubted fact, which has asserted itself through so long a period—to-day more strongly than ever—the writer conceives that there can be no question as to one proposition. If we aim at the single object of promoting the advance of knowledge in the most effective way, and making our own country the leading one in research, our efforts should be devoted toward bringing together as many scientific workers as pos-

sible at a single centre, where they can profit in the highest degree by mutual help, support and sympathy.

In thus strongly setting forth what must seem an indisputable conclusion, the writer does not deny that there are drawbacks to such a policy, as there are to every policy that can be devised aiming at a good result. Nature offers to society no good that she does not accompany by a greater or less measure of evil. The only question is whether the good outweighs the evil. In the present case, the seeming evil, whether real or not, is that of centralization. A policy tending in this direction is held to be contrary to the best interests of science in quarters entitled to so much respect that we must inquire into the soundness of the objection.

It would be idle to discuss so extreme a question as whether we shall take all the best scientific investigators of our country from their several seats of learning and attract them to some one point. We know that this cannot be done, even were it granted that success would be productive of great results. The most that can be done is to choose some existing centre of learning, population, wealth and influence, and do what we can to foster the growth of science at that centre by attracting thither the greatest possible number of scientific investigators, especially of the younger class, and making it possible for them to pursue their researches in the most effective way. This policy would not result in the slightest harm to any institution or community situated elsewhere. It would not be even like building up a university to outrank all the others of our country; because the functions of the new institution, if such should be founded, would in its relations to the country be radically different from those of a university. Its primary object would not be the education of youth, but the increase of knowledge. So far as the interests of any community or of the world-at-large are concerned, it is quite indifferent where knowledge may be acquired, because, when once acquired and made public, it is free to the world. The drawbacks suffered by other centres would be no greater than those suffered by our Western cities because all the great departments of the Government are situated at a single distant point. Strong arguments could doubtless be made for locating some of these departments in the Far West, in the Mississippi Valley, or in various cities of the Atlantic coast; but every one knows that any

local advantages thus gained would be of no importance compared with the loss of that administrative efficiency which is essential to the whole country.

There is, therefore, no real danger from centralization. The actual danger is rather in the opposite direction; that the sentiment against concentrating research will prove to operate too strongly. There is a feeling that it is rather better to leave every investigator where he chances to be at the moment, a feeling which sometimes finds expression in the apothegm that we cannot transplant a genius. That such a proposition should find acceptance affords a striking example of the readiness of men to accept a euphonious phrase without inquiring whether the facts support it. The fact is that many, perhaps the majority, of the great scientific investigators of this and of former times have done their best work through being transplanted. As soon as the enlightened monarchs of Europe felt the importance of making their capitals great centres of learning, they began to attract eminent men of other countries to their own. Lagrange was an Italian transplanted to Paris, as a member of the Academy of Sciences, after he had shown his powers in his native country. His great contemporary, Euler, was a Swiss, transplanted first to Saint Petersburg, then invited by Frederick the Great to become a member of the Berlin Academy, then again attracted to Saint Petersburg. Huyghens was transplanted from his native country to Paris. Agassiz was an exotic, brought among us from Switzerland, whose activity during the generation he passed among us was as great and effective as at any time of his life. On the Continent, outside of France, the most eminent professors in the universities have been and still are brought from distant points. So numerous are the cases of which these are examples that it would be more in accord with the facts to claim that it is only by transplanting a genius that we stimulate him to his best work.

Having shown that the best results can be expected only by bringing into contact as many scientific investigators as possible, the next question which arises is that of their relations to each other. It may be asked whether we shall aim at individualism or collectivism. Shall our ideal be an organized system of directors, professors, associates, assistants, fellows; or shall it be a collection of individual workers, each pursuing his own task in the way he deems best, untrammelled by authority?

The reply to this question is that there is in this special case no antagonism between the two ideas. The most effective organization will aim both at the promotion of individual effort, and at subordination and cooperation. It would be a serious error to formulate any general rule by which all cases should be governed. The experience of the past should be our guide, so far as it applies to present and future conditions; but, in availing ourselves of it, we must remember that conditions are constantly changing, and must adapt our policy to the problems of the future. In doing this, we shall find that different fields of research require very different policies as regards cooperation and subordination. It will be profitable to point out those special differences, because we shall thereby gain a more luminous insight into the problems which now confront the scientific investigator, and better appreciate their variety, and the necessity of different methods of dealing with them.

At one extreme, we have the field of normative science, work in which is of necessity that of the individual mind alone. This embraces pure mathematics and the methods of science in their widest range. The common interests of science require that these methods shall be worked out and formulated for the guidance of investigators generally, and this work is necessarily that of the individual brain.

At the other extreme, we have the great and growing body of sciences of observation. Through the whole nineteenth century, to say nothing of previous centuries, organizations, and even individuals, have been engaged in recording the innumerable phases of the course of nature, hoping to accumulate material that posterity shall be able to utilize for its benefit. We have observations astronomical, meteorological, magnetic, and social, accumulating in constantly increasing volume, the mass of which is so unmanageable with our present organizations that the question might well arise whether almost the whole of it will not have to be consigned to oblivion. Such a conclusion should not be entertained until we have made a vigorous effort to find what pure metal of value can be extracted from the mass of ore. To do this requires the cooperation of minds of various orders, quite akin in their relations to those necessary in a mine or great manufacturing establishment. Laborers whose duties are in a large measure matters of routine must be guided by the skill of a class higher

in quality and smaller in number than their own, and these again by the technical knowledge of leaders in research. Between these extremes we have a great variety of systems of cooperation.

There is another feature of modern research the apprehension of which is necessary to the completeness of our view. A cursory survey of the field of science conveys the impression that it embraces only a constantly increasing number of disconnected specialties, in which each cultivator knows little or nothing of what is being done by others. Measured by its bulk, the published mass of scientific research is increasing in more than a geometrical ratio. Not only do the publications of nearly every scientific society increase in number and volume, but new and vigorous societies are constantly organized to add to the sum total. The stately quartos issued from the presses of the leading Academies of Europe are, in most cases, to be counted by hundreds. The *Philosophical Transactions* of the Royal Society already number about two hundred volumes, and the time when the *Memoirs* of the French Academy of Sciences shall reach the thousand mark does not belong to the very remote future. Besides such large volumes, these and other societies publish smaller ones in a constantly growing number. In addition to the publications of learned societies, there are journals devoted to each scientific specialty, which seem to propagate their species by subdivision in much the same way as some of the lower orders of animal life. Every new publication of the kind is suggested by the wants of a body of specialists, who require a new medium for their researches and communications. The time has already come when we cannot assume that any specialist is acquainted with all that is being done even in his own line. To keep the run of this may well be beyond his own powers; more he can rarely attempt.

What is the science of the future to do when this huge mass outgrows the space that can be found for it in the libraries, and what are we to say of the value of it all? Are all these scientific researches to be classed as really valuable contributions to knowledge, or have we only a pile in which nuggets of gold are here and there to be sought for? One encouraging answer to such a question is that, taking the interests of the world as a whole, scientific investigation has paid for itself in benefits to humanity a thousand times over, and that all that is known to-day is but an insignificant

fraction of what nature has to show us. Apart from this, another feature of the science of our time demands attention. While we cannot hope that the multiplication of specialties will cease, we find that upon the process of differentiation and subdivision is now being superposed a form of evolution, tending toward the general unity of all the sciences, of which some examples may be pointed out.

Biological science, which, a generation ago, was supposed to be at the antipodes of exact science, is becoming more and more exact, and is cultivated by methods which are developed and taught by mathematicians. Psychophysics—the study of the operations of the mind by physical apparatus of the same general nature as that used by the chemist and physicist—is now an established branch of research. A natural science which, if any comparisons are possible, may outweigh all others in importance to the race, is the rising one of “eugenics,”—the improvement of the human race by controlling the production of its offspring. No better example of the drawbacks which our country suffers as a seat of science can be given than the fact that the beginning of such a science has been possible only at the seat of a larger body of cultivated men than our land has yet been able to bring together. Generations may elapse before the seed sown by Mr. Francis Galton, from which grew the Eugenic Society, shall bear full fruit in the adoption of those individual efforts and social regulations necessary to the propagation of sound and healthy offspring on the part of the human family. But when this comes about, then indeed will Professor Lankester’s “rebel against Nature” find his independence acknowledged by the hitherto merciless despot that has decreed punishment for his treason.

This new branch of science from which so much may be expected is the offshoot of another, the rapid growth of which illustrates the rapid invasion of the most important fields of thought by the methods of exact science. It is only a few years since it was remarked of Professor Karl Pearson’s mathematical investigations into the laws of heredity, and the biological questions associated with these laws, that he was working almost alone, because the biologists did not understand his mathematics, while the mathematicians were not interested in his biology. Had he not lived at a great centre of active thought, within the sphere of influence of the two great universities of England, it is quite

likely that this condition of isolation would have been his to the end. But, one by one, men were found possessing the skill and interest in the subject necessary to unite in his work, which now has not only a journal of its own, but is growing in a way which, though slow, has all the marks of healthy progress toward an end the importance of which has scarcely dawned upon the public mind.

Admitting that an organized association of investigators is of the first necessity to secure the best results in the scientific work of the future, we meet the question of the conditions and auspices under which they are to be brought together. The first thought to strike us at this point may well be that we have, in our great universities, organizations which include most of the leading men now engaged in scientific research, whose personnel and facilities we should utilize. Admitting, as we all do, that there are already too many universities, and that better work would be done by a consolidation of the smaller ones, a natural conclusion is that the end in view will be best reached through existing organizations. But it would be a great mistake to jump at this conclusion without a careful study of the conditions. The brief argument—there are already too many institutions—instead of having more we should strengthen those we have—should not be accepted without examination. Had it been accepted thirty years ago, there are at least two great American universities of to-day which would not have come into being, the means devoted to their support having been divided among others. These are the Johns Hopkins and the University of Chicago. What would have been gained by applying the argument in these cases? The advantage would have been that, instead of 146 so-called universities which appear to-day in the Annual Report of the Bureau of Education, we should have had only 144. The work of these 144 would have been strengthened by an addition to their resources, represented by the endowments of Baltimore and Chicago, and sufficient to add perhaps one professor to the staff of each. Would the result have been better than it actually has been? Have we not gained anything by allowing the argument to be forgotten in the cases of these two institutions? I do not believe that any who carefully look at the subject will hesitate in answering this question in the affirmative. The essential point is that the Johns Hopkins University did not merely add one to an already over-

crowded list, but that it undertook a mission which none of the others was then adequately carrying out. If it did not plant the university idea in American soil, it at least gave it an impetus which has now made it the dominant one in the higher education of almost every State.

The question whether the country at large would have reaped a greater benefit, had the professors of the University of Chicago, with the appliances they now command, been distributed among fifty or a hundred institutions in every quarter of the land, than it has actually reaped from that University, is one which answers itself. Our two youngest universities have attained success, not because two have thus been added to the number of American institutions of learning, but because they had a special mission, required by the advance of the age, for which existing institutions were not adequate.

The conclusion to which these considerations lead is simple. No new institution is needed to pursue work on traditional lines, guided by traditional ideas. But, if a new idea is to be vigorously prosecuted, then a young and vigorous institution, specially organized to put the idea into effect, is necessary. The project of building up in our midst, at the most appropriate point, an organization of leading scientific investigators, for the single purpose of giving a new impetus to American science and, if possible, elevating the thought of the country and of the world to a higher plane, involves a new idea, which can best be realized by an institution organized for the special purpose. While this purpose is quite in line with that of the leading universities, it goes too far beyond them to admit of its complete attainment through their instrumentality. The first object of a university is the training of the growing individual for the highest duties of life. Additions to the mass of knowledge have not been its principal function, nor even an important function in our own country, until a recent time. The primary object of the proposed institution is the advance of knowledge and the opening up of new lines of thought, which, it may be hoped, are to prove of great import to humanity. It does not follow that the function of teaching shall be wholly foreign to its activities. It must take up the best young men at the point where universities leave them, and train them in the arts of thinking and investigating. But this training will be beyond that which any regular university is carrying out.

In pursuing our theme the question next arises as to the special features of the proposed association. The leading requirement is one that cannot be too highly emphasized. How clearly soever the organizers may have in their minds' eye the end in view, they must recognize the fact that it cannot be attained in a day. In every branch of work which is undertaken, there must be a single leader, and he must be the best that the country, perhaps even the world, can produce. The required man is not to be found without careful inquiry; in many branches he may be unattainable for years. When such is the case, wait patiently till he appears. Prudence requires that the fewest possible risks would be taken, and that no leader should be chosen except one of tried experience and world-wide reputation. Yet we should not leave wholly out of sight the success of the Johns Hopkins University in selecting, at its very foundation, young men who were to prove themselves the leaders of the future. This experience may admit of being repeated, if it be carefully borne in mind that young men of promise are to be avoided and young men of performance only to be considered. The performance need not be striking: *ex pede Herculem* may be possible; but we must be sure of the soundness of our judgment before accepting our Hercules. This requires a master. Clerk-Maxwell, who never left his native island to visit our shores, is entitled to honor as a promoter of American science for seeing the lion's paw in the early efforts of Rowland, for which the latter was unable to find a medium of publication in his own country. It must also be admitted that the task is more serious now than it was then, because, from the constantly increasing specialization of science, it has become difficult for a specialist in one line to ascertain the soundness of work in another.

With all the risks that may be involved in the proceeding, it will be quite possible to select an effective body of leaders, young and old, with whom an institution can begin. The wants of these men will be of the most varied kind. One needs scarcely more than a study and library; another must have small pieces of apparatus which he can perhaps design and make for himself. Another may need apparatus and appliances so expensive that only an institution at least as wealthy as an ordinary university would be able to supply them. The apparatus required by others will be very largely human—assistants of every grade,

from university graduates of the highest standing down to routine drudges and day-laborers. Workrooms there must be; but it is hardly probable that buildings and laboratories of a highly specialized character will be required at the outset. The best counsel will be necessary at every step and in this respect the institution must start from simple beginnings and grow slowly. Leaders must be added one by one, each being judged by those who have preceded him before becoming in his turn a member of the body. As the body grows its members must be kept in personal touch, talk together, pull together, and act together.

The author submits these views to the great body of his fellow citizens interested in the promotion of American science with the feeling that, though his conclusions may need amendment in details, they rest upon facts of the past and present which have not received the consideration which they merit. What he most strongly urges is that the whole subject of the most efficient method of promoting research upon a higher plane shall be considered with special reference to conditions in our own country; and that the lessons taught by the history and progress of scientific research in all countries shall be fully weighed and discussed by those most interested in making this form of effort a more important feature of our national life. When this is done, he will feel that his purpose in inviting special consideration to his individual views has been in great measure reached.

SIMON NEWCOMB.